rainfall factor in the complex conditions of the environment of the agriculturist. In itself the rainfall regime of an area is typical of its latitude, its situation both on the continent and in relation to the ocean. Therefore, a close relationship between successful agriculture and definite rainfall conditions might have been assumed. It is the purpose of this inquiry to have laid bare, first, the validity of such an assumption, and secondly, the details regarding the relationship. It may be hoped that, in so far as agricultural progress results from purposeful guidance from without, the conclusions herein attained may serve as an indication of directions in which such progress may be most rapidly and easily achieved.

A REVOLVING CLOUD CAMERA.

By Oliver L. Fassig.

[Dated: Weather Bureau, Baltimore, Md., July 12, 1915.]

About 10 years ago a new form of camera was brought to my attention by its designer, Mr. Fred. W. Mueller, of Baltimore, with the hope that such a device might prove to be of value to meteorologists. The camera revolved upon a vertical axis by means of a spring motor, a complete revolution being made in from 5 to 10 seconds, depending upon the illumination. The image was thrown upon a film, which automatically unrolled as the camera revolved. By this means a picture was secured of the entire horizon of 360° and of the lower portions of the sky, projected upon a long and narrow sheet of paper. The device produced some very interesting and striking effects when applied to landscape photography, but where large angular sections were involved the relative positions of objects in the field of view were obviously much disturbed.

While this new camera was of general interest to me, I suggested to Mr. Mueller that a modification of his device, in order to make it possible to secure, by means of a single exposure, a complete picture of the sky from horizon to zenith and through 360° of azimuth, might prove to be of considerable value in the study of the forms and the distribution of clouds. The work of designing and constructing a suitable camera for this specific purpose was at once undertaken with enthusiasm by Mr. Mueller. Four or five years later official assignment to another field took me away from Baltimore before a camera was perfected which entirely satisfied the inventor. Upon my return to Baltimore, in the summer of 1912, one of the first visitors to call at the local office of the Weather Bureau was Mr. Mueller, bringing with him a new camera, designed and constructed by him, together with some excellent cloud photographs.

An examination of the camera and the preliminary photographs convinced me that a satisfactory method had been found for photographing, by means of a single exposure, the entire arch of the sky and all visible objects therein. The accompanying photographs, shown in figures 1 to 3, give a good idea of the general appearance and construction of the camera, while the sectional drawing, figure 4, shows how the rays of light from the various points of the sky pass through the lens and reach their proper positions on the sensitized plate or film, *bd*, within the camera.

The heavens as seen from any particular point appear to the observer as a dome, and it occurred to Mr. Mueller that to photograph the sky upon a circular plate would give a fairly true rendering of the relative positions of all objects in the sky at the time of the exposure. The photograph of the sky secured with this particular instrument is 12 inches in diameter (fig. 5), the zenith is in the center of the picture, and the horizon along the circumference. The exposure of the sensitized plate or film is accomplished in one uninterrupted operation through a wedge-shaped opening in the plate-holder cover while the plate in its holder revolves around its own axis, and the entire camera revolves around a vertical (zenithal) axis, in turn facing every point of the horizon.

The wedge-shaped opening in the plate-holder cover is about a quarter of an inch wide at the circumference of the plate and tapers to a point at the center. The vertical angle included during exposure, as the camera revolves, is 90° or from the horizon to the zenith. It will be seen, then, that, as the camera makes a complete revolution, it will include 180°, or the entire visible dome of the sky.

The body of the camera is so mounted that the plate makes an angle of 45° with the plane of the horizon and with the line to zenith. The upper segment of the revolving plate is exposed, the light from the zenith passing down vertically through the lens and striking the center of the plate, while the rays from the horizon reach the edge of the plate. (See fig. 4.)

As the camera revolves and the plate moves past the wedge-shaped opening in the plate-holder cover fresh segments of the sensitized plate are successively presented to the sky until the entire exposure is made, when the shutter automatically closes, just as it automatically opened at the beginning of the exposure.

An important feature of the instrument is the automatic shutter. The plate is contained in a circular holder, upon the cover of which is the shutter. When an exposure is to be made the cover is raised away from the plate holder—by means of the screws seen on the outside of the camera in figures 1 and 2—which then becomes a fixed part of the camera cover. This operation brings the shutter beneath the lens and at the same time automatically sets it for action.

As the plate holder revolves around its own axis the camera revolves about a vertical axis, retaining its upright position, with the lens and shutter at the top. This is effected by guides which operate in a groove around the pedestal head. The relative rate of rotation of the camera and the plate is governed by the size of the large gears connecting them, shown in figure 3. The spring motor, by means of which the camera makes a complete revolution in from 5 to 10 seconds, is shown in position in figures 2 and 3. The lens subtends an angle of 90°, has a focal length of 3 inches, and is adjusted for objects at infinite distance.

The negative produced by means of the camera requires a certain correction in order to produce a picture of the sky which shall present all objects photographed in their true relations. The axis of revolution of the plate (*dba* in fig. 4) is at an angle of 45° to the axis of revolution of the camera. The lens is fixed at the center of the upper portion of the face of the camera. Hence, as the camera revolves, the image of the sky is apparently thrown upon the interior surface of an inverted cone. (See fig. 4, *abc*.) The apex of this cone, corresponding to the zenith, is at the center of the sensitized plate (fig. 5, *Z*), while the edge of the base, which limits the rays from the horizon, corresponds to the circumference of the plate. The sides of the cone subtend an angle of 90° and are equal in length to the semidiameter of the plate. The actual image is projected upon a revolving plane surface (the plate) which is tangent to the surface of the imaginary cone. The ratio of the area of the cone to the area of the circular plate is the same as the ratio of the base to the hypotenuse of a right triangle. Hence there

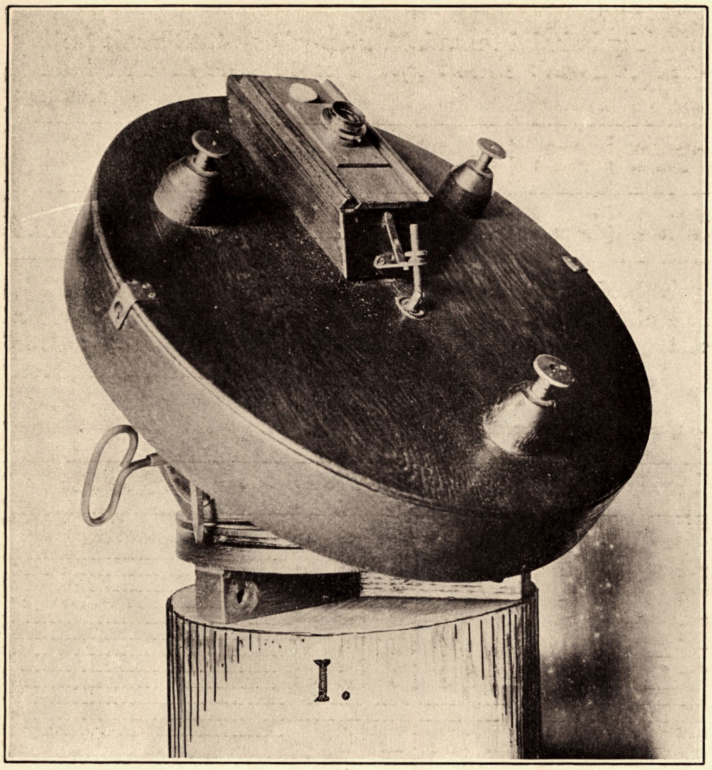

FIG. 1.—Front view of the Mueller cloud camera, showing the three screws for adjusting the plate holder and setting the shutter, and the method of mounting the lens.

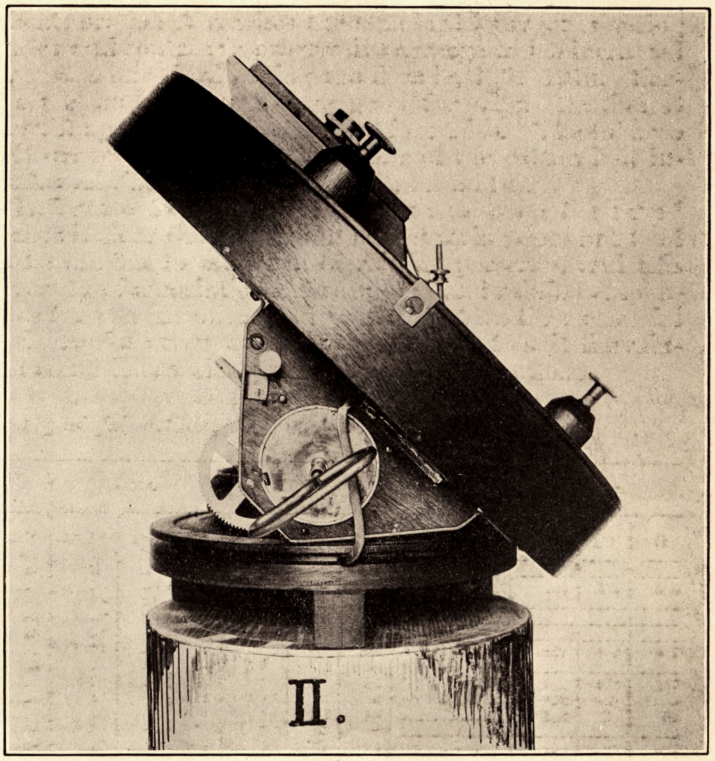

FIG. 2.—Side view of the Mueller camera, showing the inclination of the box to the horizon and part of the driving gear.

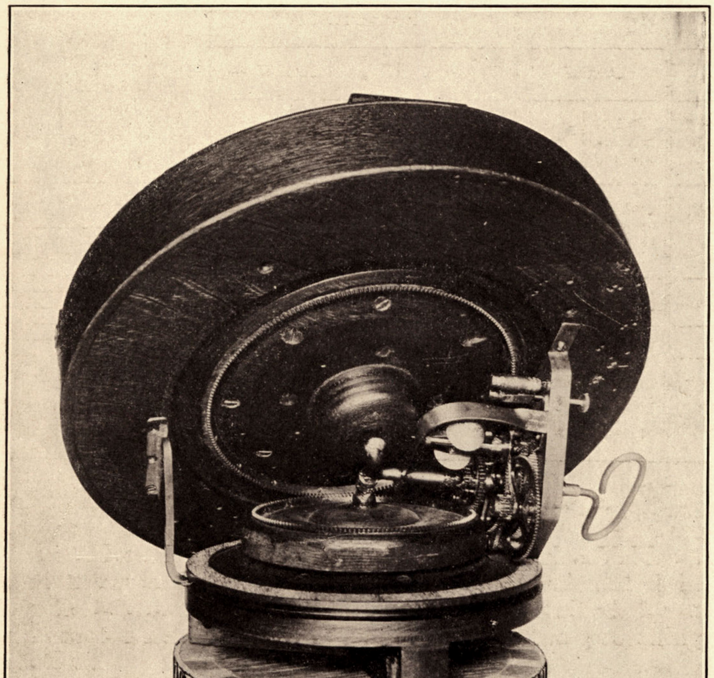

FIG. 3.—Rear view of the Mueller camera, showing the driving mechanism, the lower rack for revolving the whole box, and the inclined rack for rotating the plate holder within the box.

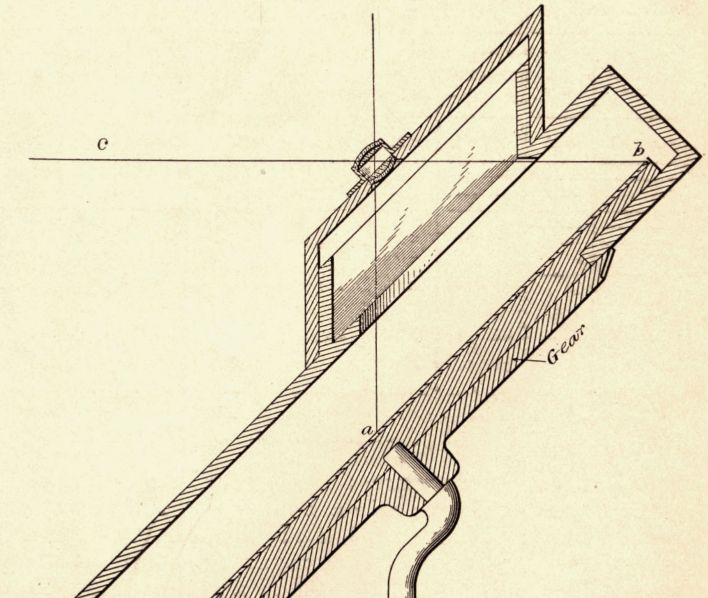

FIG 4.—Diagrammatic vertical cross section of the Mueller cloud camera, showing the cone of rays from the lens to the plate, *db*, and the cone, *cab*, to which the first print must be adjusted in order to secure the final picture shown in figure 6.

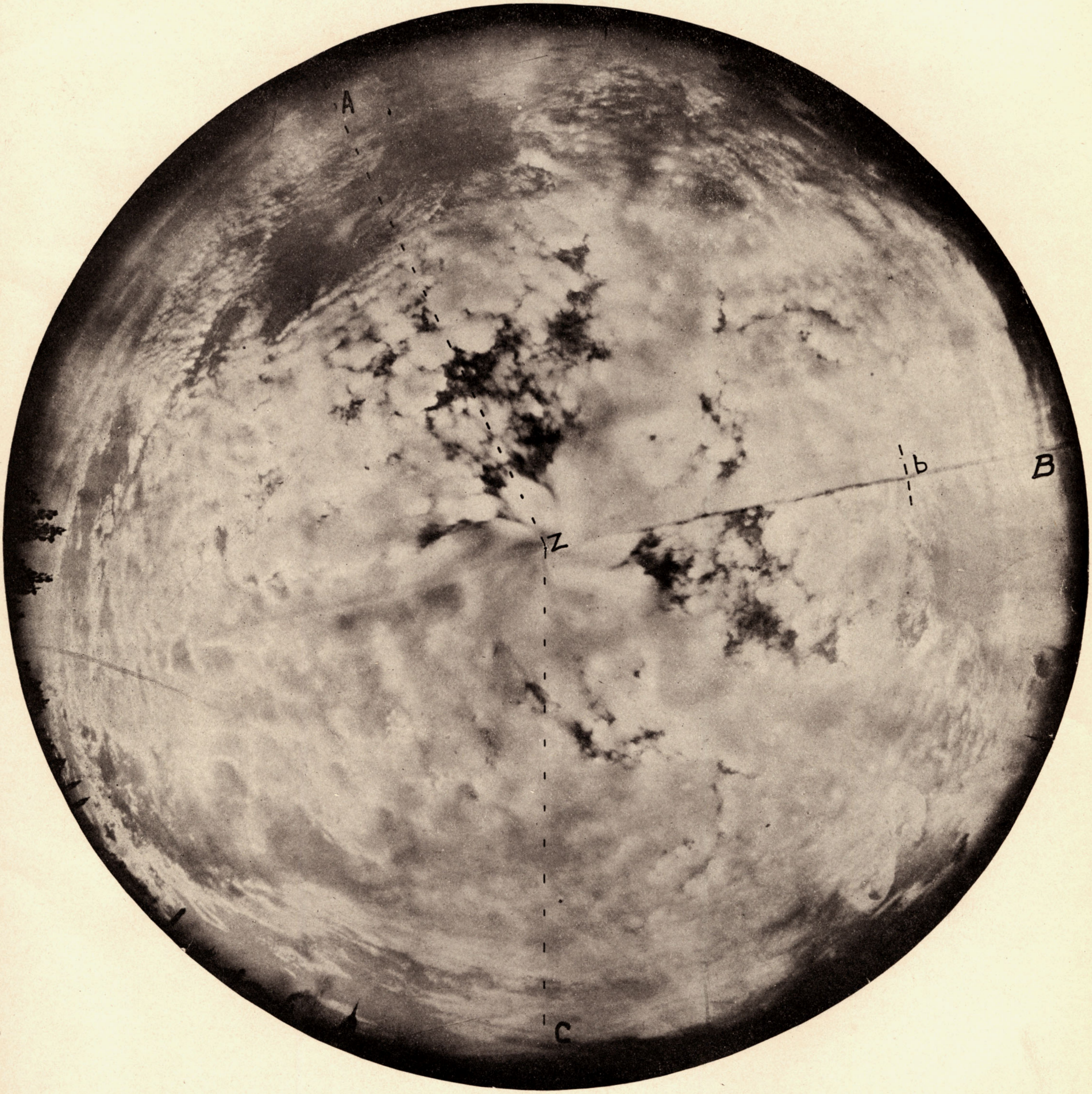

FIG. 5.—Reduced print of the uncorrected image secured by the Mueller cloud camera. (Baltimore, Md., Sept. 16, 1914, 7:45 a. m., 75th mer. time.) The segments AZB and BZC are duplicates; Z is the zenith. When this print has been corrected, its radius becomes Zb.

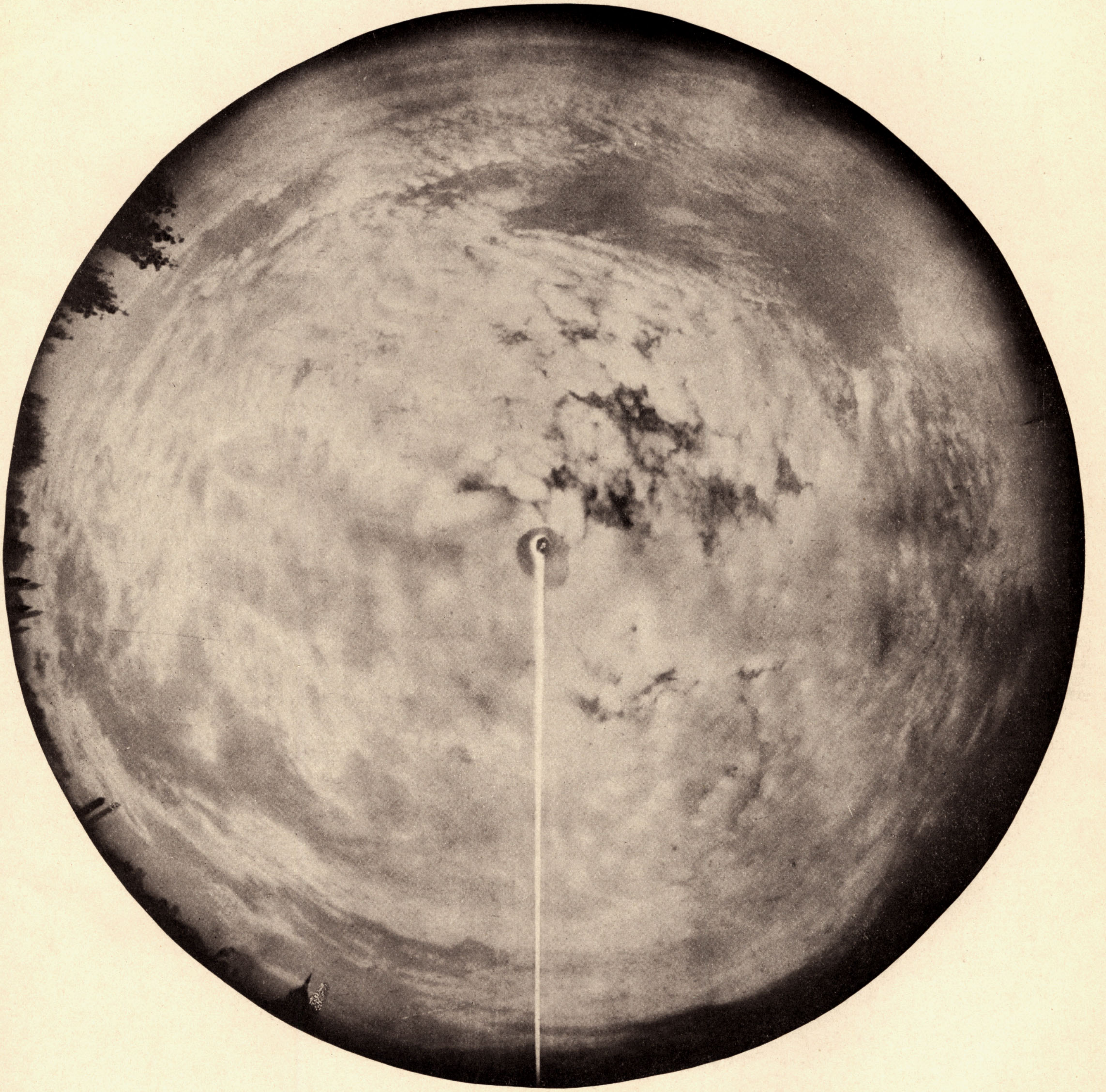

FIG 6.—Full-sized *corrected image* derived from the photograph shown in figure 5. (Baltimore, Md., Sept. 16, 1914, 7:45 a. m.

is a portion (*AZB* in fig. 5) of the sky image upon the negative which duplicates the first part of the picture. In order to obtain a correct picture of the sky the duplicating segment of the negative film is cut away and the edges are brought together. (In fig. 5 the segment *BZC* was cut away and *ZB* matched against *ZC*.) The final photograph, as shown in figure 6, is then made by means of transmitted light through the conical negative, which represents the dome of the sky. The sensitized circular film may be replaced by a conical film, with a slight modification in the construction of the camera. By the use of the conical film the size of the camera may be reduced, while the operation of cutting away the overlapping segment of the circular photograph is eliminated.[1]

Advantages of the new camera.

What advantages are offered by the use of the new form of camera, over the forms now in use, especially in the field of cloud photography? In the first place the new device can be utilized for all purposes now served by existing forms, and in addition yields results not to be obtained by means of the latter.

Our ignorance concerning cloud forms and their significance is still rather more conspicuous than our knowledge. It is reasonable to assume that a more accurate survey of cloud forms over an extended area and the rapid changes which they undergo will lead us to a better understanding of the nature and movements of storms and weather changes. A cloud is a visible process rather than a finished product, and is in many instances the only evidence we have of the forces at work in the upper atmosphere. A photograph which embraces the entire field of view opened up before the observer, and depicts all of the cloud forms—their relative positions and their extent—is manifestly of greater value than a photograph which shows only a small detached cloud, or portion of a cloud, and which gives no evidence of relationship with the general condition of the sky.

The problems of cloudiness may be profitably studied by means of a detailed study of individual cloud forms, just as it is a common and profitable practice to study forestry by the study of individual trees; there are, however, problems of clouds in association with other clouds, which can not be successfully solved in this manner, just as there are problems of trees in association with other trees, or the larger problems of forestry, which the study of individual trees will never suggest. The new form of camera will make such general cloud studies possible and profitable.

One of the simplest and most obvious uses of the new camera is to obtain a permanent and true record of the amount and character of the cloud cover at stated intervals during the day. The only method now in use to obtain this end is by means of eye observations, which are liable to errors of judgment, and at best are only rough estimates of the proportions of the sky covered by the principal cloud forms.

Photographs of the sky at stated intervals, taken simultaneously at a number of stations within cyclonic and anticyclonic areas, would afford valuable material for the advancement of our knowledge of storms. Assuming that one of these photographs will show the amount and character of the cloud cover over the area of from 200 to 300 square miles, a comparatively few stations equipped with the new camera would furnish detailed information as to practically every kind and phase of cloud form within the area of a well-developed cyclone or anticyclone.

The design of the new instrument seems to be entirely satisfactory, and the cloud photograph here reproduced in figures 5 and 6 was made by Mr. Mueller by means of the temporary wooden camera, constructed entirely by himself and shown in figures 1–4. It is very desirable, however, to provide for the construction of a more permanent instrument, in order to facilitate further experimentation in the technique of cloud photography, and to demonstrate the value of the camera as an instrument for systematic research, and for daily use at meteorological observatories.

[1] Mr. Mueller is now constructing such a modified model with a conical film in accord with these suggestions—O. L. Fassig.

A TEST FOR PERSONAL ERROR IN METEOROLOGICAL OBSERVATIONS.

By ERIC R. MILLER, Local Forecaster.

[Dated: Weather Bureau, Madison, Wis., Mar. 23, 1915.]

The object of this paper is to call attention to the value of the daily rainfall-frequency distribution as internal evidence as to the reliability of climatic data. Internal evidence is often the sole dependence of the climatologist in weighing raw data, since the observers are necessarily isolated, and hence are not subject to personal inspection and supervision. The degree of neatness of the observer's reports affords only indirect evidence of the fidelity with which the observations have been made, especially as the majority of volunteer observers—the principal source of climatic data—are likely to be above the average in general education, although they may have had no training whatever in scientific accuracy. Even this indirect evidence is not available to many who have only the neatly printed tables of data presented to their inspection.

Rainfall-frequency distribution is determined by classifying the recorded daily rainfalls according to magnitude, one class for each unit of the scale used in measuring rainfall. In the United States rainfalls are recorded to hundredths of inches, hence such a table shows the number of daily rainfalls of "Trace," 0.01 inch, 0.02 inch, 0.03 inch, and so on, in ascending series.

The frequency distribution of daily rainfalls is of the "extremely asymmetrical or J-shaped form"[1] of the statistician, the smallest amount being most frequent. In order to show that the J-shaped frequency distribution of daily rainfalls prevails throughout the widely differing rainfall regimes of the United States, I present in Table 1, and figures 1 to 5, inclusive, and figure 15, frequency distribution tables and curves for 15 United States Weather Bureau stations in the arid Southwest, the north Pacific coast, the upper Mississippi and Ohio Valleys, the Gulf States, the Lake Region and New England. These data are for the six months, April to September, inclusive, in the year 1914. Longer series would give smoother curves, as is indicated by taking the average shown graphically in figure 15. The six warmer months were chosen in order to secure, as far as possible, impersonal data, since the automatic raingages at regular Weather Bureau stations are then in operation, and while the recorded measurements are personal stick measurements, they are likely to adhere quite closely to the automatic records, especially for small amounts.

[1] Yule, G. Udny. Theory of statistics. London, 1912. p. 98.